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Modelling of Combustion and Pollutant Formation in a Large, Two-Stroke Marine Diesel Engine using Integrated CFD-Skeletal Chemical Mechanism

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ABSTRACT

In this reported work, simulation studies of in-cylinder diesel combustion and pollutant formation processes in a two-stroke, low-speed uniflow-scavenged marine diesel engine are presented. Numerical computation is performed by integrating chemical kinetics into CFD computations. In order to minimize the computational runtime, an in-house skeletal n-heptane chemical mechanism is coupled with the CFD model. This surrogate fuel model comprises 89 reactions with 32 species essential to diesel ignition/combustion processes as well as the formation of soot precursors and nitrogen monoxide (NO). Prior to the marine engine simulation, coupling of the newly developed surrogate fuel model and a revised multi-step soot model [1] is validated on the basis of optical diagnostics measurement obtained at varying ambient pressure levels [2]. It is demonstrated that the variation of ignition delay times, liftoff lengths and averaged soot volume fraction (SVF) with respect to the change of ambient pressure captured using the model agree reasonably well with the measurement, apart from those at the low pressure condition. Numerical models are subsequently validated against experimental combustion characteristics under high load condition in a marine diesel engine. Comparisons to the measurement show that the simulated pressure rise started 1.0 crank angle degree in advance and the calculated peak pressure is 1.7 % lower. The associated flame liftoff length is negligible, yielding high local equivalence ratio and SVF values. In addition, the oxygen availability is found to affect the production of acetylene and hence soot particles. For the current test condition, the averaged NO concentration calculated when soot radiative heat loss is taken into account compared to that when only convective is considered suggests that the former is approximately 7.7 % lower. The findings here aid to gain insight of in-cylinder phenomena in this combustion system. The surrogate fuel model also allows direct couplings of sulfuric oxides formation reactions and a more comprehensive nitrogen oxides mechanism since the surrogate fuel model includes essential radicals such as O, H and OH for these pollutant formation reactions.

References

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